A New Application of Ultrasound Imaging to Characterize Tissue Properties and Blood Flow in Myofascial Pain Syndromes

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Abstract— Myofascial pain syndrome (MPS) is a common, yet poorly understood, acute and chronic pain condition. MPS is characterized by local and referred pain associated with hyperirritable nodules known as myofascial trigger points (MTrPs) that are stiff, localized spots of exquisite tenderness in a palpable taut band of skeletal muscle. Our objective was to evaluate ultrasonic methods for imaging MTrPs and surrounding soft tissue. We recruited 16 subjects with acute neck pain. Based on physical examination, four sites in each patient were labeled as active MTrP (spontaneously-painful), latent MTrP (non-painful), or palpably normal. At these sites, we performed conventional B-mode and Doppler imaging; and vibration sonoelastography (VSE) by inducing vibrations (~100Hz) with a handheld vibrator. Raw RF data were acquired for offline processing. Qualitatively, three observers scored the B-mode and VSE images on a 5-point scale based on the presence and number of nodules, and the Doppler velocity spectra on a 5-point scale based on waveform morphology. Quantitatively, we estimated the spectral parameters, midband fit, zero-frequency intercept and slope, from calibrated RF spectra, and Doppler waveform parameters from spectral envelope tracings. MTrPs appeared as focal, hypoechoic nodules, and as focal regions of reduced vibration amplitude on VSE. Sites with MTrPs on physical exam were more likely to have one or more hypoechoic and/or stiffer nodules on imaging compared to normal muscle (p<0.05). Arteries near MTrPs had different flow waveform morphology with retrograde diastolic flow (p<0.02). Based on quantitative measures, MTrPs were distinct from normal muscle and active MTrPs could be differentiated from latent ones (p<0.04). With further refinement, these methods could lead to objective diagnostic criteria and clinical outcome measures for MTrPs.

Keywords—Chronic pain; myofascial trigger points; ultrasonic imaging; elastography; Doppler imaging.

I. INTRODUCTION

Chronic pain is a significant public health problem. A large majority of patients in specialty pain management centers and those with chronic pain disorders suffer from a poorly understood condition called Myofascial Pain Syndrome (MPS). Myofascial trigger points (MTrPs) are a characteristic finding in MPS [1]. MTrPs are palpable, localized painful nodules in a taut band of skeletal muscle associated with spontaneous referred pain in symptomatic patients, and are the target for treatment strategies for MPS, such as dry needle therapy. Active, or symptomatic, MTrPs (A-MTrPs) produce spontaneous pain, are acutely tender to palpation and may be associated with stiffness and restricted range of motion, while latent MTrPs (L-MTrPs) have similar physical findings but do not produce spontaneous pain symptoms [2].

There are currently no objective criteria for the diagnosis of MTrPs or for assessing clinical outcome of treatments. Physical examination is the clinical standard for identifying MTrPs, and little is known about their soft tissue environment. In preliminary studies, we have shown that MTrPs appear hypoechoic on ultrasound imaging, and are stiffer on elastography, and have unique blood flow signatures [3]. These imaging methods could lead to objective clinical outcome measures and definitive diagnostic criteria to anatomically locate MTrPs, and quantify response to treatment. The objective of this study was to evaluate the validity and inter-rater reliability of an ultrasound (US) imaging scale for visualization of myofascial trigger points (MTrPs) and adjacent soft tissue, and investigate quantitative ultrasonic tissue characterization of MTrPs.

II. METHODS AND MATERIALS

A. Participants

This study was carried out at the Rehabilitation Medicine Department of the National Institutes of Health, Clinical Research Center. Subjects with acute neck pain (< 3 months duration) were eligible and met inclusion criteria if found to have an A-MTrP in one or both upper trapezii. All subjects underwent a thorough musculoskeletal evaluation so as to rule out potential causes of their symptoms other than MTrPs. The exclusion criteria were: subjects with muscle pain due to fibromyalgia, atypical facial neuralgia and history of myopathy; neck and shoulder conditions including cervical radiculopathy, history of cervical spine or shoulder surgery and history of trigger point injections in the upper trapezius; and subjects with cancer or head, ear, eye, nose and throat infections. The Institutional Review Board of the National Institute of Dental and Craniofacial Research approved this study, and each participant provided informed consent to participate in the study.
B. Clinical Examination

Subjects underwent a physical examination by an experienced physiatrist (JPS), who determined the presence or absence of MTrPs in the upper trapezius muscle according to the standard clinical criteria defined by Travell and Simons [4]. Our clinical examination methods have been described in detail previously [3]. Up to 2 nodules were found by the examiner in each upper trapezius and identified as either an A-MTrP or L-MTrP. Any local region of myofascial tissue in which nodules were absent to palpation was defined as “normal” or uninvolved. The sonography team (SS, TG) was blinded to clinical status and identity of all sites.

C. Ultrasound Imaging

Ultrasound imaging was performed at the sites palpated during the clinical examination using a Phillips iU22 system with an L12-5 transducer and an Ultrasonix SonixTouch system with an L14-5 transducer. VSE was performed by color variance imaging while inducing vibrations at ~100 Hz using a handheld massage vibrator (North Coast Medical, Morgan Hill, CA). B-mode and VSE images were scored by three observers on a 5-point scale based on the presence and number of nodules (Figure 1).

Raw RF data were acquired using the SonixTouch system and analyzed offline using MATLAB (MathWorks Inc, Natick, MA). The backscattered RF data were gated using 2 mm sliding Hanning windows and the power spectra were calculated and normalized by a calibration spectrum obtained from a planar scatterer (glass plate) placed at the depth of 2 cm in a water bath. The least squares fit between the normalized log spectra and the square of the frequency in the 6-10 MHz bandwidth was estimated, and parametric images of the midband fit, zero-frequency intercept and slope were generated [5][6]. An observer blinded to the clinical findings at each site marked regions of interest (ROI) of suspected MTrPs using the B-mode image as a guide. The median values of midband fit and intercept within this ROI were normalized by the corresponding values in an ROI spanning the rest of the upper trapezius muscle to account for attenuation, and variable amounts of subcutaneous connective tissue.

Doppler ultrasound was used to visualize blood vessels and quantify the flow velocities at the sites of A-MTrPs, L-MTrPs and within normal myofascial tissue. During Doppler imaging, the sonographer applied two different levels of pressure using the ultrasound transducer, starting with minimal pressure with the transducer barely contacting the skin surface, and moderate pressure visibly compressing the muscle. Three observers scored the Doppler waveforms on a 5-point scale based on waveform morphology (Figure 2). The spectral Doppler velocity waveforms were analyzed to trace the peak velocity envelope throughout the cardiac cycle. The peak systolic velocity (PSV), minimum diastolic velocity (MDV), resistive index (PSV-MDV)/PSV, pulsatility index (PSV-MDV)/mean velocity), acceleration time (AT), and time-averaged peak velocity (TAPV) were computed automatically using the standard analysis software available on the ultrasound system.

D. Statistical Analysis

Comparisons were performed between the active, latent and normal sites for each of the blood flow waveform parameters. Differences between groups were assessed using the Mann-Whitney U test, since the parameter values in our study were not normally distributed. Statistical significance was determined at the 5% level for a two-tailed test.

The quantitative estimates of the median spectral midband fit, intercept and slope were compared between active, latent and normal sites using pairwise t-tests.

![Figure 1. Representative sonoelastography images showing the tissue imaging score (TIS). 0: Uniform color variance; 1: Scattered areas of decreased color variance, but no focal nodule; 2: Uniform band of decreased color variance indicating a taut band of muscle; 3: Focal decrease of color variance indicating a stiff nodule; 4: Multiple focal decreases of color variance indicating multiple nodules.](image1)

![Figure 2. Representative blood flow waveforms showing the blood flow score (BFS). 0: Resistive flow typical of muscle with no diastolic flow; 1: Low resistance flow with diastolic flow; 2: Resistive flow with no diastolic flow, and flow oscillation in early diastole; 3: Elevated flow velocities, and flow reversal in late diastole; 4: Elevated flow velocities and sustained retrograde diastolic flow.](image2)

III. RESULTS

Based on their history and physical findings in the upper trapezius muscles, 16 subjects were recruited. Three subjects were pain free at the time of the study, while the rest were diagnosed with myofascial pain. Of the 13 symptomatic subjects, all but three had bilateral pain symptoms. Based on clinical examination, a total of 74 sites were identified either as active, latent or normal. Of these, 20 were active, 16 were latent, and 20 were normal sites.
Figures 3 and 4 summarize the results of qualitative tissue imaging scores and blood flow waveform scores. There was a significant difference between normal sites and sites with MTrPs for both scores. The scores had high inter-rater reliability (intraclass correlation of 0.84 for TIS and 0.79 for BFS, respectively).

Figure 5 demonstrates differences in the quantitative spectral parameters between active and latent MTrPs and normal uninvolved muscle. The normalized midband fit (representative of integrated backscatter), and intercept (representative of acoustic concentration) parameters were significantly lower for MTrPs compared to normal muscle. The spectral slope parameter (representative of average scatterer size) was significantly lower for active MTrPs compared to latent and normal sites.

Figure 6 shows a representative active MTrP imaged using B-mode and parametric imaging. The midband fit, intercept and slope were used as the red, green and blue channels to create a pseudocolor parametric image. Connective tissue and fascia appear distinct (warmer colors) from muscle (cooler colors) on the parametric image. The hypoechoic MTrP is clearly highlighted in the parametric image.

The peak systolic velocities at active sites were significantly higher than those at latent (p<0.04) and normal sites (p<0.006), whereas the minimum diastolic velocities were significantly lower (p<0.05). Pulsatility indices at active sites were significantly higher than those at normal sites (p<0.03). No significant differences in these values were found between normal and latent sites. Other blood flow waveform measures did not show significant differences between the groups.
IV. DISCUSSION

MTrPs are definitive physical findings associated with MPS, but the inter-rater reliability of palpation is low. Our preliminary findings suggest that ultrasound imaging can distinguish between palpably normal sites in muscle and sites identified as trigger points based on palpation. MTrPs appear as hypoechoic nodules on conventional B-mode imaging. The echogenicity and echotexture of muscle is typically determined by the arrangement of the muscle fascicles and echogenic perimysial connective tissue, infiltration of fibrous and fatty tissue, and potentially fluid accumulation due to injury or ischemia [7]. In the current literature, there is no conclusive histological evidence of pathology at the site of MTrPs, although there is some suggestion of fiber disorganization associated with MTrPs.

Sonoeastography in addition to B-mode imaging incorporates complementary information about tissue stiffness. The decrease in color variance (decreased vibration amplitude) indicates a localized stiffer region, consistent with the finding of the stiffer nodule on palpation. Although we did not quantitatively estimate vibration amplitude in the present study, conventional color variance imaging provided a convenient method to highlight the MTrPs enabling a descriptive characterization of the soft tissue neighborhood as shown in Figure 1. Future work will focus on developing more quantitative estimates of the viscoelastic tissue properties of the MTrP neighborhood.

Quantitative parametric imaging further enabled a characterization of the underlying tissue structure and composition. Pseudocolor parametric images may be used as an adjunct to B-mode imaging and sonoeastography to identify MTrPs. Interestingly, our preliminary results show that active MTrPs are statistically different from latent MTrPs in terms of the spectral slope parameter, while latent and normal tissue are equivalent. This implies that regions in muscle corresponding to active MTrPs have smaller average scatterer diameters compared to latent MTrPs and normal muscle. However, the variability in our parametric measures was high. Our estimation methods can be further refined to incorporate corrections due to attenuation and signal to noise. The conventional model of the backscattered ultrasound signal may not be directly applicable to muscle, and may need refinement. We are currently investigating these aspects.

Blood flow waveforms in the vicinity of MTrPs also showed differences between normal sites and sites with MTrPs. While the qualitative scores did not differentiate between active and latent sites, peak systolic velocities and minimum diastolic velocities were significantly different between active and latent sites. The flow waveforms near active sites show increased pulsatility with significantly elevated systolic velocities and flow reversal with negative diastolic velocities. Retrograde diastolic flow can be attributed to increased vascular compliance in conjunction with an increased downstream vascular resistance. The significance of this finding needs further investigation.

V. CONCLUSION

We have demonstrated that ultrasound imaging can be used to visualize and characterize MTrPs. We have developed imaging scales that have high inter-rater reliability, and are able to distinguish MTrPs identified on clinical examination from palpably normal tissue. We anticipate that our research will facilitate the development of objective diagnostic criteria for MTrPs, and objective clinical outcome measures for assessing the success of therapeutic interventions. Quantitative measures of the tissue properties and blood flow in the neighborhood of MTrPs before and after intervention can also clarify the role of MTrPs in the pathophysiology and pathogenesis of MPS.

REFERENCES